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Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
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Protection Switching for Duplex ATM-PON Systems

Field of the invention

The present invention relates to a terminal device as defined in the outset of claim 1.

Prior Art

Asynchronous Transfer Mode (ATM) systems provide communication services over high speed, high capacity networks. The communication services can comprise various protocols for data-communication, e.g. telephone services as PSTN and ISDN, digital video/audio broadcasting, Internet services, etc. An ATM switch capable of transmitting and receiving data is connected to a range of subscribers to the communication services in a point-to-multipoint architecture ("branched tree") through a passive optical access network (PON). For reasons of clarity, an alphabetical list of relevant abbreviations is included after the description of the preferred embodiment.

In "Recommendation G.983.1" of the International Telecommunication Union (ITU-G.983.1) the requirements and specifications for the physical layer of ATM-PON systems are described in more detail.

The ATM switch is connected to the PON through an optical line terminal (OLT). Subscribers are connected to the PON through an optical network termination (ONT), which acts as an interface between the subscriber's electronic network and the optical network.

Data are sent bidirectionally over the network, using different wavelengths for upstream and downstream traffic. The ATM switch transmits data frames (of 56 data cells, each containing 53 bytes) downstream to all ONTs in the network. (Upstream, from an ONT to the ATM switch, a data frame contains 53 data cells each containing 53 bytes plus 3 bytes for traffic management). The use of an information header in the data frame and an encryption method ensures the reception of the data by only the addressed subscriber. Upstream data transmission from an ONT to the ATM switch must be synchronized with transmissions of other ONTs in the network, which is controlled by the OLT using a grant scheme by a Time Division Multiple Access

(TDMA) technique. However, due to the difference in fibre length between the OLT and each of the ONTs, the propagation time delay between signals from different ONTs must be taken into account in order to avoid collisions between upstream data frames from different ONTs. Furthermore, ONTs may exhibit an equipment-related time-delay difference. Thus, for each ONT an equalisation time delay value is established during a ranging procedure. This delay value, specific for each ONT, is used to set all ONTs at an equal "virtual distance" from the OLT in order to obtain an internal timing reference for all upstream transmissions in the network.

To enhance the reliability of an optical network, an ATM-PON system can be arranged with a protection architecture. ITU-G.983.1 (appendix D) describes optional protection schemes for network architectures in which the connection of ONTs to an ATM switch is fully established through two different passive optical networks. European patent application filed on (Lucent's reference: JNL-233-B-004), which is prior art under Art. 53 (3)/(4) EPC, describes a passive optical network architecture which allows a mix of protected and unprotected connections.

When in a protected or mixed architecture a malfunction occurs in a protected connection in one of the networks, the data traffic can be switched to the other still functioning network and continue. Disadvantageously however, due to a switching delay, a protection switch will not be hitless in the aforementioned protection architectures (i.e. without loss of data), which may severely disturb data traffic. In some protection architectures arranged with two separate networks, it is not possible to have any signals in the second of the two networks during operation of the first network due to the optical coupling arrangement of the two networks. In such a case, the second network is in a so-called cold stand-by: the laser source of the second (spare) network must be off. When a protection switch occurs, switching-on of the laser causes a delay and loss of data. In other protection architectures hot stand-by (laser on) is possible, but loss of data by a malfunction can still occur, since the data traffic in the first optical network is either not synchronised with the data traffic in the second network, or the detection of the malfunction is slow in comparison with the data transmission rate of the networks.

It is an object of the present invention to provide an arrangement and a method for a protection switch in an ATM-PON system that can reliably switch (near-)hitless between PONs, i.e. with minimal loss of data, and within maximum protection switch

time of 50 ms as specified by ITU recommendation G.783. Moreover, the present invention also provides an arrangement and a method for a protection switch to perform a per-cell selection of data, based on the quality of the received data cells on each passive optical network of the protected PON pair.

Summary of the invention

The present invention relates to a terminal device arranged for communicating data signals with a central communication device, via a first data signal carrying line and a second data signal carrying line; the first data signal carrying line being arranged for transporting a first data signal; the second data signal carrying line being arranged for transporting a second data signal, the first and second data signals having equal content; the first data signal carrying line having a first signal propagation time and the second data signal carrying line having a second signal propagation time, the first signal propagation time being shorter than the second signal propagation time; the terminal device comprising signal quality comparison means for determining a first signal quality of the first data signal and a second signal quality of the second data signal, comparing the first and second signal qualities, and accepting the one of the first and second data signals that has a better quality than the other one;
characterised in that the terminal device further comprises a first data signal buffering means for storing a data signal, and is arranged for storing the first data signal in the first data signal buffering means during a first synchronisation period to synchronise at least the reception of the first data signal and the second data signal.

Moreover, the present invention relates to a terminal device, as defined above, characterised in that the first synchronisation period equals the time difference between the second data signal propagation time and the first data signal propagation time.

Also, the present invention relates to a terminal device, as defined above, characterised in that the terminal device further comprises a second data signal buffering means, and is arranged for storing a third data signal in the second data signal buffering means during a second synchronisation period to synchronise transmission of said third data signal with transmission of a fourth data signal, the third data signal to be transmitted via said first data signal carrying line and the fourth data signal to be transmitted via said second data signal carrying line, the third and fourth data signals having equal content.

Furthermore, the present invention relates to a terminal device, as described above, characterised in that the second synchronisation period equals the time difference between the second data signal propagation time and the first data signal propagation time.

Also, the present invention relates to a terminal device, as described above, characterised in that the terminal device is a protected optical network terminal in a protected optical network architecture, and the first data signal carrying line and the second data signal carrying line are optical network fibres.

The present invention relates to an arrangement of at least one terminal device, as defined above, and a central communication device, characterised in that the central communication device is arranged to being connected to the at least one terminal via said first data signal carrying line and said second data signal carrying line.

Also, the present invention relates to an arrangement of a central communication device being arranged for communicating data signals with at least one terminal device as described above; the central communication device comprising grant controlling means for controlling transmission of the first data signal from the at least one terminal device by transmitting a first grant signal to the at least one terminal device over the first data signal carrying line and for controlling transmission of the second data signal from the at least one terminal device by transmitting a second grant signal to the at least one terminal device over the second data signal carrying line, characterised in that the grant controlling means are arranged to transmit the first and second grants signal at the same instant in time to at least one terminal device.

The present invention also relates to a method to be carried out in an arrangement of at least one terminal device, being arranged for transmission and reception of data signals with a central communication device, being connected to each other over a first data signal carrying line and a second data signal carrying line; the first data signal carrying line being arranged for transporting a first data signal; the second data signal carrying line being arranged for transporting a second data signal, the first and second data signal having equal content; the first data signal carrying line having a first signal propagation time and the second data signal carrying line having a second signal propagation time, the first signal propagation time being shorter than the second signal propagation time; the at least one terminal device comprising signal quality comparison means for determining a first signal quality of the first data signal and a second signal

quality of the second data signal, comparing the first and second signal qualities, and accepting the one of the first and second data signals that has a better quality than the other one, characterised by the following steps:

- to receive the first data signal from the central communication device,
- to store the first data signal in a first data signal buffering means,
- to receive the second data signal from the central communication device,
- to hold the first data signal in the first data signal buffering means during the first synchronisation period to synchronise at least the reception of the first and the second data signal.

Moreover, the present invention relates to a method to be carried out in an arrangement as defined above, characterised by the following steps:

- to store the third data signal in a second data signal buffering means,
- to transmit the fourth data signal to the central communication device via the second data signal carrying line,
- - to transmit the third data signal, stored in the second data signal buffering means, to the central communication device via the first data signal carrying line, after the second synchronisation period to synchronise the transmission of the third and the fourth data signal.

The present invention relates also to a computer program product to be loaded by an arrangement as defined above, after being loaded allowing said arrangement to carry out the following steps:

- to receive the first data signal from the central communication device,
- to store the first data signal in a first data signal buffering means,
- to receive the second data signal from the central communication device,
- to hold the first data signal in the first data signal buffering means during a first synchronisation period to synchronise at least the reception of the first and the second data signal.

In addition~~, the present invention~~ relates to a computer program~~-product as~~ defined above, characterised by the following steps:

- to store the third data signal in a second data signal buffering means,
- to transmit the fourth data signal to the central communication device via the second data signal carrying line,

- - to transmit the third data signal, stored in the second data signal buffering means, to the central communication device via the first data signal carrying line, after the second synchronisation period to synchronise the transmission of the third and the fourth data signal.

Moreover, the present invention relates to a data carrier provided with a computer program product as defined above.

Brief description of the drawings

Below, the invention will be explained with reference to some drawings, which are intended for illustration purposes only and not to limit the scope of protection as defined in the accompanying claims.

Figure 1 shows a schematic overview of a prior art network architecture of two passive optical networks comprising a plurality of protected and unprotected connections between an OLT and multiple ONTs;

Figure 2 shows an example of an OLT downstream cell bridge for a protected connection;

Figure 3 shows a schematic block diagram of a protected optical network terminal ONT1;

Figure 4 shows diagrammatically an ONT downstream receiver for a protected connection in a PON pair;

Figure 5 shows diagrammatically an ONT upstream transmitter for a protected connection in a PON pair;

Figure 6 shows diagrammatically a PON-LT protection switch for a protected connection in a PON pair;

Figure 7 shows diagrammatically a PON-LT medium access control grant generator for a protected connection in a PON pair.

Description of preferred embodiment

To achieve a (near) hitless protection switch in a protected or mixed passive optical network architecture, the present invention provides an arrangement and method as will be described below. In Figure 1, a prior art passive optical network architecture 1 is shown, which comprises an Asynchronous Transfer Mode switch ATM1, which is connected to a backbone network 2 and to a plurality of optical network terminals through passive optical networks PON-A, PON-B, PON-C and PON-D. The ATM

switch ATM1 comprises an optical line terminal OLT, in which a plurality of optical line interfaces PON-LT1, PON-LT2, PON-LT3, PON-LT4 are located. Optical line terminals PON-LT1, PON-LT2, PON-LT3 and PON-LT4 are coupled to the passive optical networks PON-A, PON-B, PON-C and PON-D, respectively. For reasons of clarity, in this figure only connections on PON-A and PON-B are shown. On networks PON-A and PON-B, a plurality of optical network terminals ONT1, ONT2, ONT3 is connected in a point-to-multipoint configuration ("tree and branch topology") through optical splitters OS1 and OS2. To provide a protected connection between the ATM switch ATM1 and the terminal ONT1, the terminal ONT1 is connected to both networks PON-A and PON-B. In the network architecture 1 also unprotected connections may exist for terminal ONT2 in network PON-A and terminal ONT3 in network PON-B, respectively. It will be appreciated that within the limits of the network architecture, any number of optical networks interfaced with the ATM switch ATM1 may be possible. It is to be understood that also within the limits of the network architecture, any combination of protected and unprotected optical network terminals may be present.

In a protected network architecture 1, the passive optical networks PON-A and PON-B preferably, encompass geographically different routes to minimise failure probability due to mechanical damage to the fibre cables like e.g., cable cuts. It will be appreciated that in this network architecture a data frame to a protected network terminal ONT1 is transmitted over both networks PON-A and PON-B: both networks are active simultaneously.

Figure 2 shows a schematic block diagram of an optical line terminal OLT to transmit data downstream, comprising a network interface NI, a data packaging unit DPU1, Lookup Table Array LTA, Cell filters CF, Cell Buffers CB1, CB2, CB3, Cell mergers CMA, CMB and physical layer units PHYA, PHYB.

In the OLT unit data from the ATM switch ATM1 entering electronically from ~~the backbone 2~~ through interface NI, is transmitted ~~into one or both of the~~ optical networks PON-A, PON-B. A data packaging unit DPU1 determines in conjunction with the virtual path identification lookup table array LTA whether the data must be sent to a protected terminal ONT1 or an unprotected terminal ONT2, ONT3. If an unprotected terminal must be addressed on network PON-A or PON-B, the cell filters CF activate a cell buffer CB1 or CB2 for a transmission to an unprotected terminal ONT2 or ONT3,

respectively. In case a protected terminal ONT1 is addressed, cell buffer CB3 is activated. Subsequently, the data is transferred to the respective cell buffer CB1, CB2, CB3 and through a cell level handshaking mechanism sent at the appropriate time to the respective cell mergers CMA and/or CMB. Finally, the physical layer unit PHYA, PHYB handles the conversion of the data from the electronic domain to the optical domain, including churning, scrambling and insertion of grants in the downstream PLOAM (Physical Layer Operations Administration and Maintenance) cells for network operation and management through grant control code inputs GC-A, GC-B. In Figure 7 the insertion of grants in the downstream PLOAM cells will be described in more detail.

Due to differences in fibre length in networks PON-A and PON-B between the ATM switch ATM1 and each of the network terminals ONT1, ONT1, ONT3, differences in propagation delays will exist for signals travelling between ATM switch ATM1 and each of the network terminals ONT1, ONT2, ONT3. Each network terminal ONT1, ONT2, ONT3 is provided with an equalisation time delay: to provide synchronisation within one passive optical network, in each network terminal ONT1, ONT2, ONT3 the specific value for the equalisation time delay is used to set each terminal at a virtual distance from the ATM switch, equal for each network terminal. A network terminal ONT1, ONT2, ONT3 delays its transmission of a data signal during a time-span equal to the equalisation time delay in order to synchronise its data traffic with the data traffic of other network terminals. As described by ITU-G.983.1 in each network PON-A, PON-B for each network terminal ONT1, ONT2, ONT3 the equalisation time delay is determined during a ranging procedure.

The equalisation time delay Td_{ji} for an optical network terminal ONTi in a passive optical network PON-j is given by:

$$Td_{ji} = Trtvd_j - (2 * Tp_j + Ts)$$

where $Trtvd_j$ is the round-trip delay at a predetermined virtual distance between the optical line interface PON-LTj and the network terminal ONTi in optical network PON-j, Tp_j is the actual propagation delay time between the network teminal ONTi and the optical line interface PON-LTj in PON-j, and Ts is the intrinsic equipment delay time due to internal latency in the network terminal ONTi, respectively.

From this equation it follows that the shorter the actual distance between the optical line terminal OLT and the optical network terminal ONTi, the longer the equalisation delay time Td_{ji}.

In the present invention, an arrangement on the downstream side is provided for a protection switch between optical networks PON-A and PON-B. Principally identical data frames sent to the network terminal ONT1 over both PON-A and PON-B need to be compared to identify possible errors and / or malfunctions on one of the respective networks. Although each network PON-A, PON-B is internally synchronised, data transmitted from ATM switch ATM1 to a protected optical network terminal ONT1 will most probably not be received at ONT1 in the same instant through both networks PON-A and PON-B, due to the difference in the propagation delay between the optical networks (i.e. the equalisation time delay for ONT1 in network PON-A will not be equal to the equalisation time delay for ONT1 in network PON-B: $Td_{A1} \neq Td_{B1}$). Thus, nearly hitless protection switching for a possible malfunction in one of the networks is difficult to achieve. Advantageously, synchronisation between the two networks PON-A and PON-B at a network terminal ONT1 can be obtained by providing an adaptive buffer on the network terminal for buffering data signals propagating over the network with the larger equalisation time delay until the same data signal propagating over the network with the smaller equalisation time delay have arrived. The adaptive buffer will be described further in Figures 4 and 5.

From the ranging procedures on network PON-A and PON-B, the equalisation time delay Td_{A1}, and Td_{B1}, respectively, for a protected network terminal ONT1 are known. On the network with the larger equalisation delay time ("shorter propagation time, shorter distance") data will be received earlier than through the other "longer" network. The incoming frames from the "shorter" network must be buffered during a time of ΔTd until the same data is received through the "longer" network. The buffering time ΔTd for downstream data traffic in a protected optical network terminal ONTi connected to networks PON-j and PON-k is derived from the equalisation time delay values (based on round-trip delays) for the network terminal ONTi in network PON-j and PON-k, respectively, and given by the following equation:

$$\Delta Td = (Td_{ji} - Td_{ki}) / 2$$

where $Td_{ji} > Td_{ki}$.

Since the distance between each optical network terminal ONTi and the optical line terminal in the respective networks is "scaled" by the ranging procedure to the same virtual distance with the same virtual round–trip delay Trtvd, the difference ΔTd can be used as buffer time delay to synchronise incoming data from both optical networks.

In Figure 3 a schematic block diagram of a protected optical network terminal ONT1 is shown. The network terminal ONT1 is connected to optical network PON-A and to optical network PON-B. The optical network terminal ONT1 comprises a receiver part R-ONT1 for reception of data signals from both networks PON-A and PON-B, and a transmitter part T-ONT1 for transmission of data signals to both networks PON-A and PON-B. The optical network terminal ONT1 further comprises optical coupling devices OC-A and OC-B for coupling the receiver part R-ONT1 and transmitter part T-ONT1 to the networks PON-A and PON-B, and an interface IL1 to a data-communication network, for example a local area network LAN1. The receiver part R-ONT1 and transmitter part T-ONT1 are interlinked for exchange of control signals, as will be described later. The local area network LAN1 facilitates telephony and data-communication services as known in the art for data-communication devices such as personal computers.

In Figure 4 a schematic block diagram of the receiver R-ONT1 of a protected optical network terminal ONT1 is shown.

The receiver R-ONT1 comprises for each optical network PON-A, PON-B an optical receiver unit OR1, OR2, a cell delineation and descrambling unit CDD1, CDD2 coupled to a PLOAM cell analysis unit PCA1, PCA2. Further the receiver contains an adaptive delay buffer ADB1 comprising a memory to store data, a downstream protection switch control unit DPSC1 and a data conversion unit DC1.

Data from optical network PON-A, and PON-B are received by optical receivers OR1 and OR2, respectively, and converted from the optical to the electronic domain. From the receiver OR1, OR2 the data are sent to the cell delineation and descrambling units CDD1, CDD2 and analysed for loss of signal LOS-A, LOS-B and loss of cell delineation LCD-A, LCD-B.

Coupled to CDD1, CDD2, the PLOAM cell analysis units PCA1, PCA2, checks the received PLOAM data for errors ERR-A, ERR-B, loss of PLOAM frame synchronisation FRML-A, FRML-B, and loss of Operations Administration and Maintenance data OAML-A, OAML-B. The PLOAM cell analysis units PCA1, PCA2 send their error-related data to the downstream protection switch control unit DPSC1. Grant information GR1, GR2 for upstream transmission to the respective optical line interface PON-LT1, PON-LT2 is sent to the transmitter part of the optical network terminal T-ONT1 (i.e. the grant delay time insertion units GDTI1 and GDTI2, shown in Figure 5).

Based on the equalisation delay time determined for each optical network PON-A, PON-B during the ranging procedure, the cell delineation and descrambling units CDD1, CDD2 send the received data to the adaptive data buffer ADB1 or directly to the data conversion unit DC1. The data received as a data packet through the network with the larger equalisation time delay (e.g. PON-A) is buffered in the adaptive data buffer ADB1 until arrival of the same data received as a data packet through the optical network with the smaller equalisation time delay (e.g. PON-B).

Based on the possible errors detected by the cell delineation and descrambling units CDD1, CDD2, and the PLOAM cell analysis units PCA1, PCA2 (i.e. LOS-A, LOS-B, LCD-A, LCD-B, ERR-A, ERR-B, FRML-A, FRML-B, and OAML-A, OAML-B), the downstream protection switch control unit DPSC1 determines which one of the data packets received through PON-A and PON-B will be used to pass on to the data conversion unit DC1 for a further processing step as known by persons skilled in the art (i.e. decryption, translation of header information, etc.). In case both data packets are error-free, either one of the received data packets can be passed on. In case only one of the data packets is error-free, the downstream protection switch control unit DPSC1 will select the error-free data packet.

In Figure 5 a block diagram schematically depicts an upstream transmitter part T-ONT1 of a protected optical network terminal ONT1.

The transmitter part T-ONT1 comprises a user network interface UNI, a data packaging unit U1, a cell queue CQ, an adaptive delay time buffer ADB2, an upstream protection switch control unit UPSC1, PLOAM cell insertion units PCI1, PCI2, signal converter units SC1, SC2, optical transmitters OT1, OT2, and grant delay time insertion units GDTI1, GDTI2.

Data to be transmitted, enter the transmitter part T-ONT1 through the UNI interface. The data packaging unit U1 determines the ATM traffic category for the data frame. Also, the data packaging unit U1 arranges the data into data frames, in which also a data header is inserted. A data frame is then sent to the cell queue unit CQ where the data frame is stored per category. When transmission is granted by the OLT, the optical line interfaces PON-LT1, PON-LT2 send grant signals in a PLOAM signal over PON-A, PON-B respectively to the receiver part R-ONT1 of ONT1. From the PLOAM signals received through PON-A and PON-B, the respective PLOAM analysis unit PCA1, PCA2 generate a grant signal GR1, GR2, respectively, which are sent to the transmitter part T-ONT1. (see Figure 3 and 4). In T-ONT1, the grant signals GR1, GR2 from PCA1 and PCA2 are sent to the grant delay time insertion units GDTI1 and GDTI2, respectively. The upstream protection switch control unit UPSC1 now monitors grant delay time insertion units GDTI1 and GDTI2 to regulate the transmission of a data frame waiting in cell queue CQ.

The transmission of a data frame waiting in cell queue CQ is now granted by the signal from the "longer" optical network with the smaller equalisation time delay (e.g. PON-B). The transmission for the "shorter" optical network with the larger equalisation time delay (e.g. PON-A) must still be delayed for a time ΔTd, in order for the data frame to arrive at the optical line terminal in sync with the same data frame transmitted over the "longer" network. The additional delay is achieved by the implementation of an adaptive delay time buffer ADB2. Similarly as for the implementation of the adaptive delay time buffer ADB1 in the receiver part of the optical network terminal R-ONT1, the upstream protection switch control unit UPSC1 determines during the ranging procedure which optical network to buffer with the appropriate buffer time delay ΔTd.

Both the data directly transmitted over the "longer" network and the same data transmitted with a delay over the "shorter" network are further processed as known in the art: the data are merged with PLOAM cells and minislots by units PCI1 and PCI2, converted (scrambled) by signal converters SC1 and SC2 and, finally, converted from the electronic to the optical domain by the optical transmitters OT1 and OT2.

It is noted here that since GDTI1 and GDTI2 do not buffer their respective grant data GR1 and GR2 in the adaptive delay buffer ADB2, the grant delay time insertion units GDTI1 and GDTI2 must delay the respective grant signals GR1 and GR2

internally with a delay Td_{A1}+Ts and Td_{B1}+Ts equal to the sum of the equalisation time delay Td_{A1}, Td_{B1} for the respective network, and the intrinsic equipment delay Ts of the optical network terminal ONT1. The delay time used by the grant delay time insertion units GDTI1 and GDTI2, respectively, is also applied in unprotected optical network terminals ONT2, ONT3, as known to persons skilled in the art.

In Figure 6, the receiver part R-PON-LT of an optical line terminal OLT is schematically shown as a block diagram. The receiver part R-PON-LT of the OLT comprises a data packaging unit DPU2 connected to ATM switch ATM1, a protection switch control unit PSCU, and optical line interfaces PON-LT1 and PON-LT2 which are connected to the passive optical networks PON-A and PON-B, respectively. In PON-A, optical line interface PON-LT1 comprises an optical receiver ORU1, a cell recovery unit CR1, an upstream slot code input SCIA and a PLOAM analysis unit PA1. Similarly, in PON-B, optical line interface PON-LT2 comprises an optical receiver ORU2, a cell recovery unit CR2, an upstream slot code input SCIB and a PLOAM analysis unit PA2.

Due to the timing of the transmission of data by the optical network terminal ONT1, the data will be received synchronously by the optical receivers ORU1 and ORU2 of the optical line interface PON-LT1 and PON-LT2, respectively. Optical receiver ORU1, ORU2 converts the optical signal comprising the data to the electronic domain and sends the data to the cell recovery unit CR1, CR2 which recovers the data with information data (expected cell code information ECCI) received through the upstream slot code input SCIA, SCIB from the medium access grant generation processor MAGG. The MAGG will be described below in Figure 7. The cell recovery unit CR1, CR2 determines the loss of signal LOSi-A, LOSi-B and the loss of cell delineation LCDi-A, LCDi-B for each protected optical network terminal ONTi, individually. The necessary information for which protected network terminal ONTi the loss occurred, is derived from the expected cell code information ECCI, received through the upstream slot code ~~input SCIA, SCIB.~~

The PLOAM analysis unit PA1, PA2 recovers the PLOAM cells, minislots and ranging cells from the data frame. Also, for each data frame the PLOAM analysis unit PA1, PA2 determines the occurrence of errors ERRi-A, ERRi-B, loss of PLOAM frame synchronisation FRMLi-A, FRMLi-B, and loss of Operations Administration and Maintenance data OAMLi-A, OAMLi-B, for each protected optical network terminal

ONTi, individually. The necessary information for which protected network terminal ONTi the loss occurred, is derived from the expected cell code information, received through the upstream slot code input SCIA, SCIB.

Based on the possible errors detected by the cell recovery units CR1 and CR2, and the PLOAM analysis units PA1 and PA2, the protection switch control unit PSCU determines which one of the data frames received through PON-A and PON-B will be used to pass on to the data packaging unit DPU2 for further transmission over the backbone network 2. In case both data frames are error-free either one can be passed on. In case only one of the data frames is error-free, the protection switch control unit PSCU will select the error-free data frame.

To synchronise the downstream data traffic from the optical line interfaces PON-LT1 and PON-LT2 over the networks PON-A and PON-B, respectively, to a protected network terminal ONT1, it is essential that the transmission of grants by means of the PLOAM cells is synchronised as well. The grants for protected optical network ONT1 must be placed in the same field position in both upstream PLOAM cells transmitted over PON-A and PON-B, respectively. Only in this way a specific data frame can arrive simultaneously at both the optical receivers ORU1 and ORU2 of the optical line terminal OLT. The scheduling of grants in the present invention is done by a medium access grant generation processor MAGG.

In Figure 7 a schematic block diagram of a medium access grant generation processor MAGG is shown. The medium access grant generation processor MAGG comprises interfaces IPA, IPB to the physical layer units PHYA, PHYB, a plurality of grant generators GGP for protected optical network terminals, a plurality of grant generators GGA and GGB for unprotected optical network terminals on both optical networks PON-A and PON-B, respectively. The grant generators GGP, GGA, GGB are provided with FIFO buffers FIFO-P, FIFO-A, FIFO-B, respectively, to store the pending grants. Furthermore, the medium access grant generator processor MAGG comprises a grant insertion scheduler ~~GIS, and time~~ delay buffers TVDA, TVDB.

For every upstream cell slot, the grant insertion scheduler GIS determines in which order the pending grants, generated in the grant generators GGP, GGA and GGB and buffered, are directed from the respective buffers FIFO-P, FIFO-A, FIFO-B into the interfaces IPA, IPB for insertion into downstream cells transmitted over PON-A and PON-B. Grants for a protected optical network terminal ONT1 are generated in

grant generator GGP and simultaneously inserted in both PLOAM cells of PON-A and PON-B by sending the grants to the grant control code inputs GC-A and GC-B of the optical line terminal OLT, as shown in Figure 2.

It is noted here that in conjunction with the generation of grants for a protected optical network terminal ONT1, the expected cell code information data ECCI is generated for the slot code input SCIA, SCIB of the receiver part R-PON-LT of the optical line terminal OLT (Figure 6). The data cell, to be transmitted by the protected network terminal ONT1 and related to the grants generated by the MAGG, has a round trip delay (until received by the optical line terminal OLT after the instant of transmission of the grants) equal to the virtual distance time delay Trtvd, for transmission over network PON-A and PON-B, respectively. To synchronise the expected cell code information ECCI with the arrival of the related data cell, the time delay buffers TVDA, TVDB store the expected cell code information during the round trip delay Trtvd, respectively, before sending the expected cell code information to the slot code information input SCIA, and SCIB, respectively.

Grants for an unprotected optical network terminals ONT2 on PON-A and ONT3 on PON-B are generated in grant generators GGA and GGB, respectively, and sent through the interfaces IPA and IPB, respectively to the grant control code inputs GC-A and GC-B, respectively, of the optical line terminal OLT, as shown in Figure 2. For a grant directed to an unprotected optical network terminal the MAGG performs in a similar way: for the unprotected optical network terminal ONT2 connected to the OLT over the optical network PON-A, the expected cell code information is delayed only in time delay buffer TVDA during a delay time Trtvd, before sending the ECCI information to the slot code input SCIA.

Based on which grants are generated for the respective PON, PLOAM cells for unprotected optical network terminals are different for both optical networks PON-A and PON-B. If no more grants for unprotected network terminals are pending at a certain time, the grant field in the PLOAM cell is padded with an unassigned grant UAG in order to keep the grants in the PLOAM cells for the protected network terminal ONT1 synchronised on both networks PON-A and PON-B. The PLOAM signals received by the receiver part R-ONT1 of a protected optical network terminal ONT1 are handled as explained with reference to the grant signals GR1, GR2 shown in Figure 5.

The object of the present invention is to provide that protection, in the embodiment as described above, is performed in such a way that no (or maximum one) data cell is lost. This is obtained by overall synchronisation, i.e. synchronisation of grants, issued downstream, and synchronisation of the received data cells in both directions, at the protection path selection points. In this embodiment, the present invention is providing protection for one or more ONTs in PONs that connect both protected and unprotected ONTs.

In the embodiment as described above, the protection switching arrangement in the OLT and in the ONT, respectively, allows the switching off of one PON, if necessary. This can be done within the time interval of one data cell within the data frame, since the data traffic on both PON-A and PON-B is transmitted and received synchronously in the present invention. As soon as differences occur, the protection switch can switch to use only the proper data transmitted over one of the PONs, without (almost) any interruption of data traffic noticeable to the users.

Alphabetical list of abbreviations

ADB	adaptive data buffer
ATM	asynchronous transfer mode
CB	cell buffer unit
CDD	cell delineation and descrambling unit
CF	cell filter unit
CM(A/B)	cell merger unit
CQ	cell queue
CR	cell recovery unit
DC	data conversion unit
DPU	data packaging unit
DPSC	downstream protection switch control unit
ERR	error
FIFO	first in first out buffer
FRML	loss of PLOAM frame synchronisation
GC-(A/B)	grant control code input (PON-A/PON-B)
GDTI	grant delay time insertion unit
GG(A/B)	grant generator
GGP	protected grant generator

GIS	grant insertion scheduler
GR	grant signal
IL	LAN interface
IP(A/B)	interface to physical layer unit (PHYA/PHYB)
ISDN	integrated services data network
LAN	local area network
LCD	loss of cell delineation
LOS	loss of signal
LTA	lookup table array
MAC	medium access control
MAGG	medium access control grant generator
NI	network interface
OAML	loss of Operations Administration and Maintenance data
OLT	optical line terminal
ONT	optical network terminal
OR	optical receiver (in ONT)
ORU	optical receiver (in OLT)
OSU	optical network subscriber unit
OT	optical transmitter
PCA	PLOAM cell analysis unit
PCI	PLOAM cell insertion unit
PHY(A/B)	Physical layer unit (A/B)
PLOAM	Physical Layer Operations Administration and Maintenance
PON	passive optical network
PON-LT	passive optical network line terminal (optical line interface)
PSCU	protection switch control unit
PSTN	public switched telephone network
R-ONT	receiver part of ONT
SC	signal converter
SCI(A/B)	upstream slot code input (PON-A/PON-B)
T-ONT	transmitter part of ONT

Td_{ji}, (Td_{A1}, Td_{B1})	equalisation time delay for an optical network terminal ONTi in a passive optical network PON-j, (ONT1 in PON-A, ONT1 in PON-B)
Tp	propagation time delay
Ts	internal equipment delay time
TVD(A/B)	time delay buffer (PON-A/PON-B)
UNI	user network interface
UPSC	upstream protection switch control unit
Trtvd	round-trip delay at predetermined virtual distance
ΔTd	buffer time delay

Claims

1. A terminal device (ONT1) arranged for communicating data signals with a central communication device (OLT), via a first data signal carrying line and a second data signal carrying line; the first data signal carrying line being arranged for transporting a first data signal; the second data signal carrying line being arranged for transporting a second data signal, the first and second data signals having equal content; the first data signal carrying line having a first signal propagation time and the second data signal carrying line having a second signal propagation time, the first signal propagation time being shorter than the second signal propagation time; the terminal device comprising signal quality comparison means (CDD1, CDD2, PCA1, PCA2, DPSC1) for determining a first signal quality of the first data signal and a second signal quality of the second data signal, comparing the first and second signal qualities, and accepting the one of the first and second data signals that has a better quality than the other one;

characterised in that

the terminal device (ONT1) further comprises a first data signal buffering means (ADB1) for storing a data signal, and is arranged for storing the first data signal in the first data signal buffering means (ADB1) during a first synchronisation period to synchronise at least the reception of the first data signal and the second data signal.

2. A terminal device (ONT1), according to claim 1, characterised in that the first synchronisation period equals the time difference between the second data signal propagation time and the first data signal propagation time.

3. A terminal device (ONT1), according to claim 1, characterised in that the terminal device (ONT1) further comprises a second data signal buffering means (ADB2), and is arranged for storing a third data signal in the second data signal buffering means (ADB2) during a second synchronisation period to synchronise transmission of said third data signal with transmission of a fourth data signal, the third data signal to be transmitted via said first data signal carrying line and the fourth data signal to be transmitted via said second data signal carrying line, the third and fourth data signals having equal content.

4. A terminal device (ONT1), according to claim 4, characterised in that the second synchronisation period equals the time difference between the second data signal propagation time and the first data signal propagation time.

5. A terminal device (ONT1), according to any of the preceding claims, characterised in that the terminal device (ONT1) is a protected optical network terminal in a protected optical network architecture, and the first data signal carrying line and the second data signal carrying line are optical network fibres.

6. Arrangement of at least one terminal device (ONT1), as claimed in the preceding claims 1-5, and a central communication device (OLT), characterised in that the central communication device (OLT) is arranged to being connected to the at least one terminal (ONT1) via said first data signal carrying line and said second data signal carrying line.

7. Arrangement of a central communication device (OLT) being arranged for communicating data signals with at least one terminal device (ONT1) as claimed in the preceding claims 1-6; the central communication device comprising grant controlling means (MAGG) for controlling transmission of the first data signal from the at least one terminal device (ONT1) by transmitting a first grant signal (GR1) to the at least one terminal device (ONT1) over the first data signal carrying line and for controlling transmission of the second data signal from the at least one terminal device (ONT1) by transmitting a second grant signal (GR2) to the at least one terminal device (ONT1) over the second data signal carrying line,
characterised in that
the grant controlling means (MAGG) are arranged to transmit the first and second grants signal (GR1, GR2) at the same instant in time to at least one terminal device (ONT1).

8. A method to be carried out in an arrangement of at least one terminal device (ONT1), being arranged for transmission and reception of data signals with a central communication device (OLT), being connected to each other over a first data signal carrying line and a second data signal carrying line; the first data signal carrying line

being arranged for transporting a first data signal; the second data signal carrying line being arranged for transporting a second data signal, the first and second data signal having equal content; the first data signal carrying line having a first signal propagation time and the second data signal carrying line having a second signal propagation time, the first signal propagation time being shorter than the second signal propagation time; the at least one terminal device comprising signal quality comparison means (CDD1, CDD2, PCA1, PCA2, DPSC1) for determining a first signal quality of the first data signal and a second signal quality of the second data signal, comparing the first and second signal qualities, and accepting the one of the first and second data signals that has a better quality than the other one;

characterised by the following steps:

- to receive the first data signal from the central communication device (OLT),
- to store the first data signal in a first data signal buffering means (ADB1),
- to receive the second data signal from the central communication device (OLT),
- to hold the first data signal in the first data signal buffering means (ADB1) during the first synchronisation period to synchronise at least the reception of the first and the second data signal.

9. A method to be carried out in an arrangement according to claim 8, characterised by the following steps:

- to store the third data signal in a second data signal buffering means (ADB2),
- to transmit the fourth data signal to the central communication device (OLT) via the second data signal carrying line,
- - to transmit the third data signal, stored in the second data signal buffering means (ADB2), to the central communication device (OLT) via the first data signal carrying line, after the second synchronisation period to synchronise the transmission of the third and the fourth data signal.

10. A computer program product to be loaded by an arrangement as claimed in the preceding claims, after being loaded allowing said arrangement to carry out the following steps:

- to receive the first data signal from the central communication device (OLT),
- to store the first data signal in a first data signal buffering means (ADB1),

- to receive the second data signal from the central communication device (OLT),
- to hold the first data signal in the first data signal buffering means (ADB1) during ~~a first synchronisation period to synchronise at least the reception of the first and~~ the second data signal.

11. A computer program product in accordance with claim 10, characterised by the following steps:

- to store the third data signal in a second data signal buffering means (ADB2),
- to transmit the fourth data signal to the central communication device (OLT) via the second data signal carrying line,
- to transmit the third data signal, stored in the second data signal buffering means (ADB2), to the central communication device (OLT) via the first data signal carrying line, after the second synchronisation period to synchronise the transmission of the third and the fourth data signal.

12. A data carrier provided with a computer program product as claimed in any of the claims 10, 11.

Abstract

A terminal device (ONT1) arranged for communicating data signals with a central communication device (OLT), via a first signal carrying line and a second signal carrying line; the first signal carrying line being arranged for transporting a first signal; the second signal carrying line being arranged for transporting a second signal, the first and second signals having equal content; the first signal carrying line having a first propagation time and the second signal carrying line having a second propagation time, the first propagation time being shorter than the second propagation time; the terminal device comprising signal quality comparison means (CDD1, CDD2, PCA1, PCA2, DPSC1) for determining a first signal quality of the first signal and a second signal quality of the second signal, comparing the first and second signal qualities, and accepting the one of the first and second signals that has a better quality than the other one.

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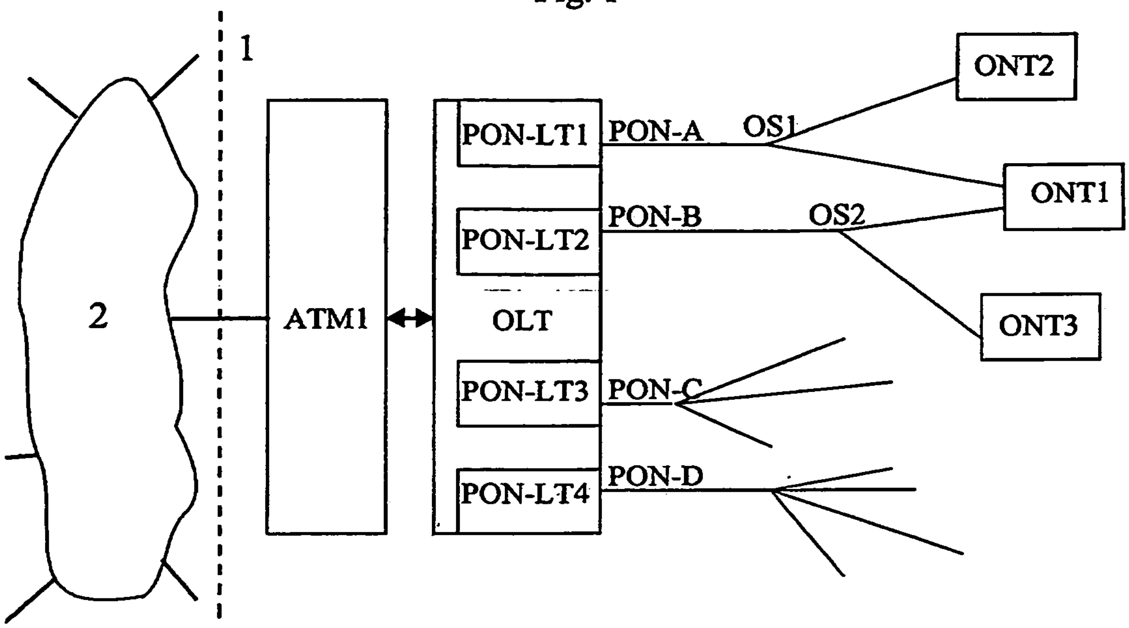
Fig. 1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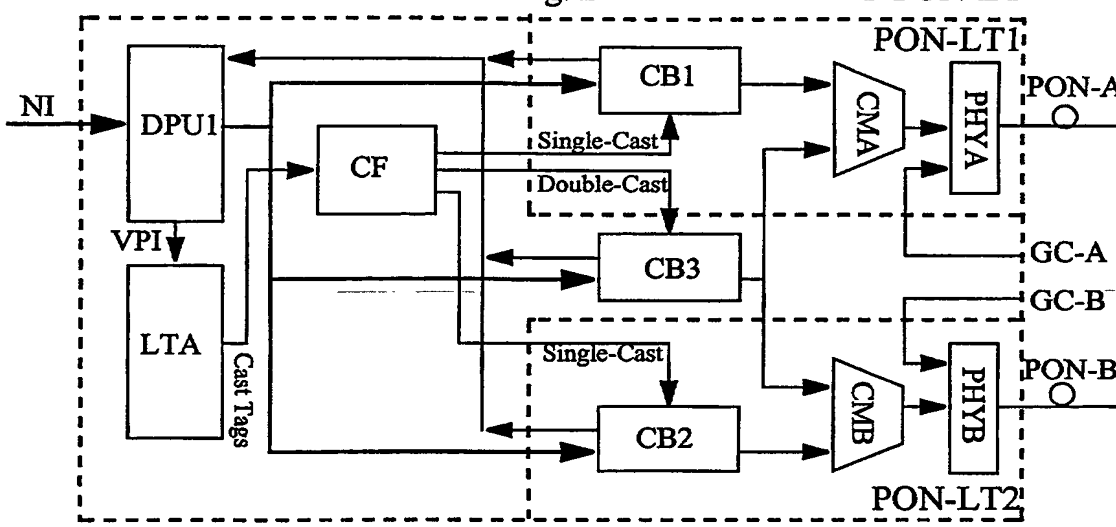
ONT1
ONT2
ONT3

Fig. 2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PON-LT2

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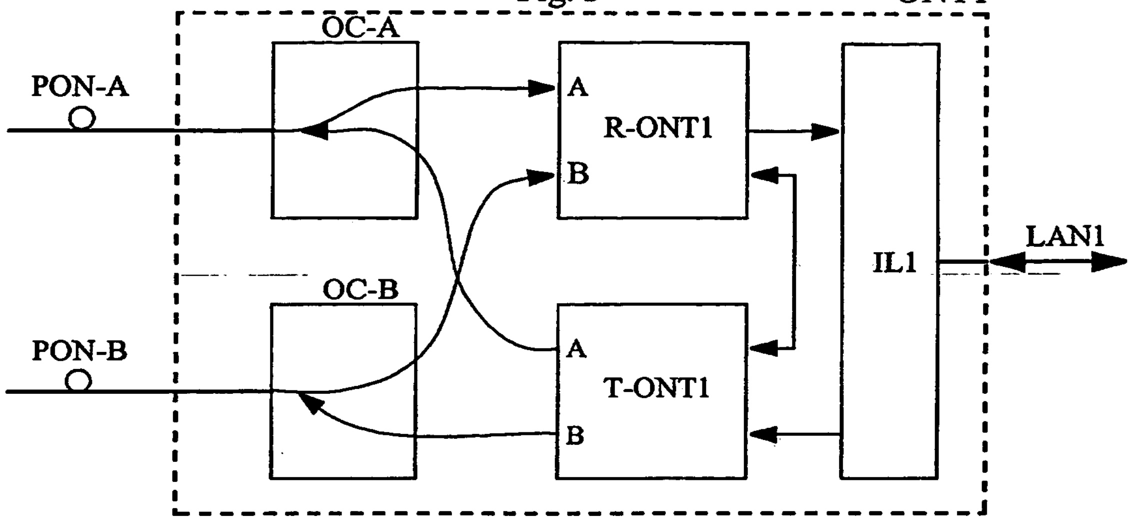

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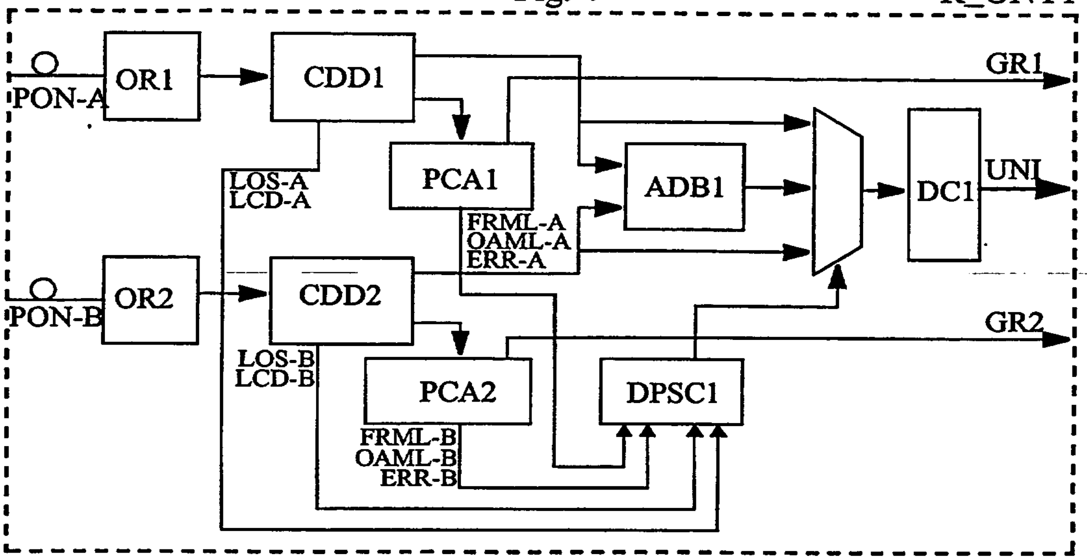
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ERR-A
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Fig. 5

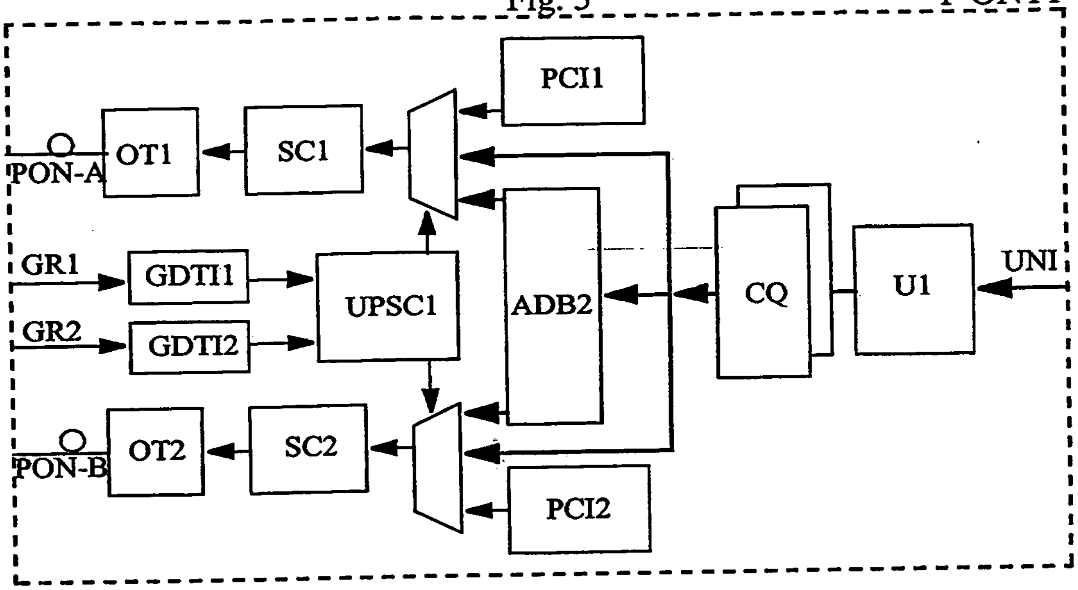
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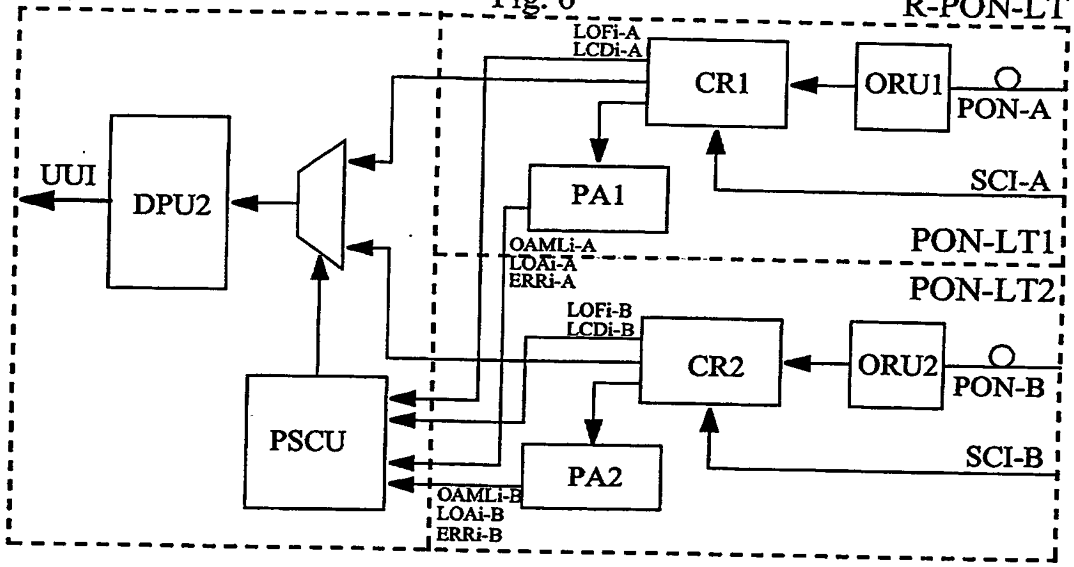
Fig. 6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ERRi-A
PON-LT1
PON-LT2
LOFi-B
LCDi-B
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ORU2
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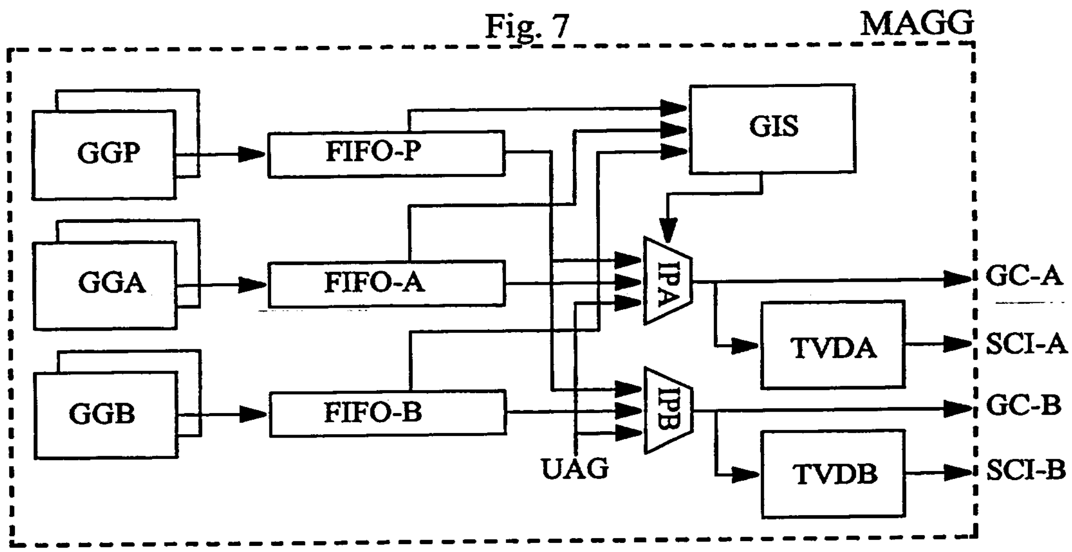
PSCU
PA2
SCI-B
OAMLi-B
LOAi-B
ERRi-B

Fig. 7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TVDB
SCI-B